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National biology reforms often define evolution as the unifying concept in biology. However, few inservice teachers have an understanding of this role. The purpose of this study was to evaluate the effectiveness of a course sequence in evolution designed for inservice biology teachers on their conceptions of the role of evolution in biology. Twenty-two teachers attended a course for two quarters. The course covered the history and mechanics of evolutionary theory, included a 12-day field trip to the Galapagos Islands, and ended with a synthesis of course materials into classroom lesson plans. Teachers' views of the role of evolution in biology did not change as a result of the program. No significant change occurred in the number of the teachers who included evolution in their descriptions of biology (approximately 50%), with only two teachers recognizing the unifying role of biology. At the conclusion of the course, teachers were as likely to define evolution as a subordinate concept in biology as they were to describe it as the superordinate theory tying disparate biology topics into a coherent whole. Despite a course specifically designed to present evolution as the unifying theory in biology, the teachers were unwilling or unable to change previously held views of biology. (PR)

Teachers' Views of the Role of Evolution in the Structure of Biology

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**********ABSTRACT**********

National biology reforms often define evolution as the unifying concept in biology. However, few inservice teachers have such an understanding of this role. The purpose of this study was to evaluate the effectiveness of a course sequence in evolution designed for inservice biology teachers on their conceptions of the role of evolution in biology. Twenty-two teachers attended a two-quarter course that covered the history and mechanics of evolutionary theory, included a 12-day field trip to the Galapagos Islands, and ended with a synthesis of course materials into classroom lesson plans. Teachers' views of the role of evolution in biology did not change as a result of the program. No significant change occurred in the number of the teachers who included evolution in their description of biology (approximately 50%), with only two teachers recognizing the unifying role of biology. At the conclusion of the course, teachers were as likely to define evolution as a subordinate concept in biology as they were to describe it as the superordinate theory tieing disparate biology topics into a coherent whole. Despite a course specifically designed to present evolution as the unifying theory in biology, the teachers were unwilling or unable to change previously held views of biology.

Teachers' Views of the Role of Evolution in the Structure of Biology

Introduction

The field of biology, like that of all of the sciences, is becoming more and more specialized. This specialization often translates itself into textbooks that resemble small encyclopedias and classroom practice that presents biology content as a set of fragmented topics with few relationships among the topics established. Current science reform movements have rallied against this conceptual isolation and have called for the renewed emphasis on teaching science thematically with an emphasis on a few conceptually power ideas that bind the content knowledge presented into a coherent whole (AAAS, 1989; BSCS, 1992; NRC, 1989, 1993) .

The role of evolution as the unifying concept that organizes and gives meaning to the diverse fields of study in biology has been often championed. Science for All Americans (AAAS, 1989) states that "the modern concept of evolution provides a unifying principle for understanding the history of life on earth, relationships among all living things, and the dependence of life on the physical environment" (pg. 64). If students of the 21st century are to be biologically literate, and if biology instruction is to become more than the meaningless memorization of vocabulary and disconnected facts, the importance of accurate and adequate instruction in biology with evolution as the unifying theme is critical (Demasters & Wandersee, 1992). But do biology teachers possess such an integrative understanding of evolution? If not, what strategies exist to address this issue?

Research has shown that despite "certifiable" biology content background, many teachers enter the teaching profession with misconceptions about evolution (Affanato, 1986; Roelfs, 1987; Shankar, 1989; Tatina, 1989; VanKovering & Stiehl, 1989; Zimmerman, 1987). Perhaps more importantly, few teachers enter the teaching profession possessing a unifying conceptual framework for biology, much less understanding the potential power of evolutionary concepts in this role (Gess-Newsome & Lederman, 1993). The advantage of teachers having a conceptual structure in place for the content they teach has been discussed in the literature (Clark & Doyle, 1987; Gess-

Newsome & Lederman, 1993, in press; Lederman, Gess-Newsome & Latz, 1994). Possession of such structures is an attribute of content "experts" and aids in the acquisition and teaching of content knowledge from a unified framework (Berliner, 1987).

Of the factors related to the quality and quantity of instructional time spent on evolution in the public schools, teacher academic background has been cited as the most influential (Shankar, 1989). As recognized by many (i.e., Peebles, 1992; Scharmann & Harris, 1992), courses for teachers that specifically address teachers' comfort level with evolutionary content and the integrative role of evolution in biology content are needed if we hope to affect changes in classroom practice. Scharmann and Harris (1992) have demonstrated that such a course can have a significant impact on teachers' understandings of evolution content and can reduce anxieties regarding the teaching of evolution.

Recent work in the assessment of teachers' conceptions of the structure and organization of biology topics has used open-ended questionnaires in contrast to more researcher-directed means of gaining this information, such as card-sort techniques. Work by Gess-Newsome and Lederman (1993) has demonstrated that preservice biology teachers, as a result of their college content course work, often hold fragmented conceptions of biology content. Rarely can teachers at this stage in their careers provide examples of overlying concepts or fundamental understandings that tie the content of biology together, such as evolution. Descriptions of the "big picture" of biology were often reported as simple listings of the content courses taken while obtaining certification. With consist reinforcement of ideas and conceptions that can conceptually tie science topics together (i.e., the nature of science, science process skills, science-technology-society interactions) in science-specific methods classes, preservice teachers were found to move toward more integrated views of science. None of the students used biology content (i.e., evolution, ecology) as an integrative mechanism for their content understandings.

A study of five inservice biology teachers (X = 12 years of biology teaching experience) held varying degrees of a structure that conceptually unified the biology content they taught.

Though the integrated nature of biology was recognized by all, only two of the teachers were able to articulate the nature of this integration or provide specific examples of how this integration could or should be put into instructional practice (Gess-Newsome, 1991; Gess-Newsome & Lederman, in press). Teachers with explicit structures for biology based these integrations on generic principles of science (i.e., nature of science, science process skills, science-technology-society interactions) or on the structure of biology content with evolutionary processes as the conceptual glue for the remainder of the content. The formation of well articulated conceptual structures for biology were credited to time for content reflection gained either through typical teaching activities (i.e, selection of textbooks, curriculum development) or attendance in courses with an emphasis on enhancing teachers' understanding of biology content.

The purpose of this research was to evaluate the effectiveness of a two-quarter course in Biological Evolution, designed for inservice biology teachers, on their conceptions of the role of evolution in biology. The course was designed to purposefully engage teachers in the exploration of a number of fields of science and biology that impact evolution (i.e., geology, genetics, molecular biology, botany, zoology, ecology). Therefore, it was hypothesized that the course would allow biology teachers to form a more closely integrated view of biology with evolution forming the basic framework that organized all other biological knowledge and linked it to the other sciences.

Evolution Course and Field Trip Sequence

A two-quarter course sequence in Biological Evolution was offered in a large western university during the 1992-3 academic year and was supported by a three-year NSF grant. Only the results of the third year of the grant will be described in this report. The purpose of the course was to enhance the preparation of practicing biology teachers in order to "significantly increase the[ir] knowledge and appreciation of Biological Evolution." Biological Evolution was described by the course instructor as "one of the most fundamental of the important theories and principles of science... It focuses our intellectual outlook on change - a dynamic rather than static world view, ... [and encompasses the] diversity of the living world, how different forms interact, how they arose

and are continuing to arise." The course was developed and taught by a noted scientist in evolutionary theory with 33 years of college teaching and research experience.

The first course (five quarter hours) was offered during the Winter Quarter. Content included coverage of the mechanisms of evolution (i.e., origins of life, genetic control, population genetics, reproductive isolation, natural selection, current research in evolution) as well as original readings (i.e., Darwin, Mendel, McClintock) detailing the historic development of evolution and its impact on Western thought. The second course (three quarter hours) included participation in a twelve-day field trip to the Galapagos Islands during spring break where the teachers were to "observe first hand the unusual, often unique plants, animals and geology that triggered Darwin's ideas on how the dynamics of the evolutionary process actually worked." The remainder of the course (ten weeks) consisted of the presentation of research reports and lesson plans prepared by the participants on a topic of interest selected as a result of the field trip. All reports and lesson plans were printed in book format for the participants. Tuition, fees, materials and travel costs for the field trip were covered by the NSF grant.

Subjects

Twenty-two teachers were selected to attend the final year of the program. Applications from biology teachers around the state were solicited through districts and schools. Criteria for selection included a current teaching assignment that involved Biology instruction, a desire to complete all aspects of the program, and release time to attend the field trip guaranteed by an administrator. Forty-six teachers completed applications and were involved in a 20 minute interview with project staff. Final selection of participants was conducted by a panel of school district and university representatives. The teachers were selected to attend based upon their proven ability and commitment to share information with colleagues, the number of biology courses taught, and school district distribution. Consideration was sometimes granted in favor of reactivated applications and designated alternates from previous years.

The 11 male and 11 female biology teachers selected for this program came from 15 of the

42 high schools, 2 of the 124 junior high schools, and 1 of the 17 alternative public schools in the state. Eighteen of the teachers came from urban districts, 4 from rural districts. Teaching experience averaged 11.8 years, with a range from 3 to 29 years. All teachers were certified by the state and taught biology as their primary teaching responsibility (X = 4.6 biology related classes per teacher, range = 3-6). Six teachers had completed a masters degree prior to the course sequence, and six were in the process of completing a masters degree during the program period.

Fifty-five percent of the participants were of Mormon (LDS- Church of Jesus Christ of Latter Day Saints) background. This percentage is consistent with that of the population found in the urban areas of the state. The religious background of the population is an important consideration since many members of the church perceive anti-evolution pressures from the church, though this is not the case in terms of church doctrine. Since the state core curriculum mandates the teaching of evolution, and students are held accountable for this content in end-of-level state testing, many teachers find themselves in personal and political conflict when teaching this content.

Data Collection and Analysis

The data obtained for this study was part of a larger effort to document the impact of the program on participants. Only the data pertinent to potential changes in teachers' conceptions of the role of evolution in the structure of biology will be presented as part of this study. Written applications and transcripts of random application interviews were analyzed to determine demographic information, teaching experience, and the basis for selection of the participating teachers.

Since past use of open-ended questionnaires on teachers' conceptions of subject matter have proven useful in determining their conceptual structure and appear sensitive to changes in this structure, similar procedures were determined to be the most appropriate for this study. All participants in the Winter section of the class were asked to fill out the pretest (Figure 1) during the second week of class. The first questions (1a, b & c) dealt directly with teachers' conceptions of the structure of biology. The presence or absence of evolution in this diagram was used as a base-

line indicator of teachers' conceptions prior to the course sequence. Questions 2a & b were included to analyze whether the answer to Question 1 dealt with teachers' conceptions of biology or biology teaching. Past research has raised the possible concern that individuals cannot view their content separate from the manner in which it is used, in this case, the teaching context (Gess-Newsome & Lederman, 1992; Hauslein, Good & Cummins, 1992). Since a change in either of these views would indicate a positive impact of the program on teachers' thinking, both questions were posed to determine if teachers considered the answers to the questions to be similar or different.

---------Insert Figure 1 here--------

During the two quarter course sequence, field notes and audiotapes were collected during each of the class sessions. Information on the Galapagos field trip was collected via field notes and copies of a random sample of the participant's trip journals. Copies of all materials produced by both the program staff and participants were collected and analyzed for content.

During the second to last week of the Spring Quarter, the teachers were asked to complete a post-test questionnaire concerning their current views of the structure of biology, their views of the structure of evolution, and a comparison between the two (Figure 2). Since contaminating the data with the suggestion that evolution might be a concept that could tie biology together was no longer a concern, the specific inclusion of Question 2a-d was an attempt to directly assess whether teachers saw such a connection.

---------Insert Figure 2 about here--------

Research Questions and Data Analysis

Both qualitative and quantitative data analysis procedures were used to answer the following specific questions:

RQ-1. What is the nature of teachers' inclusion of evolution in their conceptions of biology before and after the course sequence? (qualitative)

RQ-2. Do teachers see their conceptions of biology and biology teaching as the same or different? (quantitative)

RQ-3. Would there be an increase in the number of teachers who included evolution in their post-course conceptions of biology than in their pre-course conceptions of biology? (quantitative)

RQ-4. Would more teachers credit changes in their post-course conceptions of biology to specific elements of the course? (quantitative)

RQ-5. Would there be an increase in the number of teachers who included evolution as a unifying theme in their post-course conceptions of biology? (quantitative)

RQ-6. What is the nature of teachers' conceptions of evolution after the course? (qualitative)

RQ-7. Do teachers attribute changes in their conceptions of evolution to aspects of the inservice course sequence? (qualitative)

RQ-8. What is the relationship between teachers' views of biology and evolution? (quantitative)

Qualitative Analysis: Data from all questionnaires were analyzed following qualitative methodology in which the answers to each question were read across participants (Bogdan & Biklen, 1982). Categories for each of the answers were derived based upon patterns that emerged from the data. Diagrams of conceptions of biology (question 1a & b, pre and post-test) and conceptions of evolution (questions 2a & b, post-test) were analyzed for basic content. Biology conceptions were specifically analyzed to determine if and/or how evolution was included in teachers' conceptions of biology prior to and following the course sequence. Evolution diagrams were analyzed as to the nature of the description of evolution (integrative or compartmentalized). Written comparisons of the biology and evolution diagrams were categorized.

Quantitative Analysis: Categorization schemes based upon participants' answers were formed, applied to pre and post-test data, and the number of answers in each category tallied. Answers from questions 1c (pre and post) and 2c (post) were tallied and explanations categorized for pre to post-test comparison. All data was initially separated by organizational categories derived from the qualitative analysis of the diagram in order to detect potential patterns.

A comparison between teachers' conceptions of biology and biology teaching was conducted to assess the transfer of these beliefs among contexts and to judge the validity of using two separate questions to assess views of biology and biology teaching. If no significant difference

in the answers were perceived by the teachers (predetermined percentage = 66.7%), it would be determined that asking a single question of this nature during the post-test would be sufficient. Chi square analyses were performed where pre/post comparisons were possible. Data categories were collapsed in order to maintain a cell size of at least five. An alpha level of 0.05 was selected to determine significance.

Results and Discussion

Sixteen teachers completed the pretest. Although 22 teachers attended the Galapagos field trip and Spring Quarter class, six of the teachers had taken the Winter class in years prior to 1993 and had resubmitted earlier applications to attend the field trip and subsequent class. Pretest data was not available for these teachers.

Pre-course Conceptions of Biology and Biology Teaching

RQ-1: If one were to generalize the basis for content organization by the teachers in this sample, the majority tied their conceptions of biology to ecological relationships and principles rather than to the theory of evolution. When asked to describe their conceptions of the "big picture" of biology, 43.75% of the teachers indicated that evolution had a role in their conceptions (see Table 1), with 12.5% indicating that evolution was the central unifying theme of biology (Figure 3). Eighteen percent of this group included evolution as an integral component of their diagram (Figure 4), whereas 12.5% seemed to include evolution only as an afterthought. This inference was based upon the location of evolution in the diagram, typically last (Figure 5). Of the six teachers that did not specifically include evolution in their diagram (Figure 6), two mentioned the integrated nature of biology but did not give specific information concerning how the concepts listed were integrated.

----------Insert Table 1 here----------

Ten of the 16 teachers claimed that they had always thought of biology in the manner described. Of the four teachers who claimed that their views had changed, they indicated that their conceptions of biology had increased in complexity, broadened, and become more integrated with

maturity and experience, a finding similar to that of Gess-Newsome and Lederman (in press). One teacher also mentioned that change had occurred due to classroom experience in dealing with student learning and motivation.

----------Insert figures 3, 4, 5, 6 & 7 about here----------

RQ-2: Of the teachers that answered Question 2b (pretest), the majority (85.7%) felt that their conceptions of biology were the same as their conceptions of biology teaching. Although a few teachers added conceptions or descriptions of the role of students or learning, these diagrams (if a second one was drawn) were specific to pedagogical issues (Figure 7) as opposed to integrated with issues of content. This is consistent with the findings of other researchers (Hauslein, et al., 1992; Lederman, et al., 1994) who suggested that teachers' conceptions of subject matter were built around the context of knowledge use, such as the act of teaching. Of the two teachers who claimed that these conceptions were different, the difference was based upon interaction with students, goals for student learning, the mandated curriculum, and resources for teaching. Based upon this analysis of the pretest data, the similar conceptions of the structure of biology and biology teaching (85.7% > 66.7%) allowed for the elimination of the second question on the post-test.

When asked if they had always thought about biology teaching in the manner described on the pretest, most of the teachers (76.9%) responded positively. Of the three teachers who felt that their views of biology teaching had changed, all credited experience in teaching as formalizing what they originally considered only vague ideas about the structure of biology teaching.

Post-Course Conceptions of Biology

Twenty-two participants attended the Galapagos field trip during spring break. However, due to distance from campus, four of the students participated in the Spring Quarter course correspondence. Therefore, post-test data was available for only 18 of the 22 participants. Pre and post-test data was available for 12 of the participants.

RQ-3: When asked to describe their conceptions of biology on the post-test questionnaire

(Table 2), the proportion of teachers who included evolution as one of a number of topics in biology remained constant ($X^2_{(1,0.05)} = 0.25$, NS). As in the pretest, two teachers in the sample described evolution as the central unifying concept, though these were not the same two teachers. If Table 2 is compared to that of the pretest, teachers' conceptions of the structure of biology in terms of the role of evolution did not appear to change as a result of this program.

----------Insert Table 2 about here ----------

RQ-4: When asked if they had always thought of the "big picture" of biology in the way described on the post-test (Table 2), 44.44% said that their conceptions were stable, 22.22% indicated some change with the overall structure remaining the same, 33.33% said that their conceptions had changed. Overall, 55.55% of the group indicated that some shifts had been made in their conceptions of biology on the post-test. This is a significant change ($X^2_{(1,0.05)} = 6.43$) over the number in the pretest who recognized recent changes in their conceptions (28.5%). Teachers in the pretest who felt that their conceptions of biology had changed described such changes in the following ways:

> "It has changed with experience, knowledge, and perceptions of how students learn and how they are motivated."
>
> "I guess the more I learn the more I have moved from the idea of biology as a collection of facts into the idea of interrelated concepts."
>
> "The more knowledge I receive, the more complex the picture becomes. Same basic outline though."

Teacher who stated that their views of biology had changed at the time of the post-test offered the following explanations:

> "As I get more and more knowledge, I see how much they all interrelate."
>
> "Due to teaching - not when I was a university student, but when I became a student in order to teach more knowledgeably."
>
> "I would say that I have become more aware of the common threads that ties all life together."
>
> "My thoughts have become more refined. My perspective has not changed, just broadened."

Though significantly more teachers indicated that their views had changed at the conclusion of the program, the reasons given for these changes on the post-test do not vary significantly from comments made on the pretest.

RQ-5: As noted earlier, the two teachers who indicated that evolution was the central unifying theme in biology in the post-test were not the same two teachers who voiced this conception in the pretest. Table 3 shows the pre to post-test changes in teachers' views. The intersection of the rows and columns indicates the shift in stated conceptions. Using movement toward a conception of evolution as the unifying conception for biology content as an indication of a positive shift based upon the course content, four teachers shifted toward this conception, four were neutral or made no movement from their original conceptions, and four moved away from this originally stated conception in the pretest. This movement appears to be almost random and may be a function of the instrument used or the result of unique conceptual shifts by individual teachers.

--------- Insert Table 3 about here ---------

Post-Course Conceptions of Evolution

RQ-6: In order to compare teachers' conceptions of evolution with those of biology, specific questions addressed this issue in the post-test questionnaire. Of the diagrams produced by the teachers concerning evolution (Table 4), 50% discussed the specific integrative nature of evolution across biology (Figure 8) and/or geology topics (Figure 9). This is in contrast to the relatively low percentage of teachers who expressed integrative or unifying views of evolution in biology when asked the question concerning this structure during the pre and post-tests (12.5% and 11.1% respectively). Thirty-three percent of the diagrams were evolution specific (Figure 10) indicating the possibility that these teachers had compartmentalized the information gained about evolution into a "unit" package, both for the purposes of their conceptual understanding and for teaching.

---------Insert Table 4 about here---------

RQ-7: Fifty-five percent of the teachers claimed changes in their views concerning the

nature of evolution, 38.8% felt that their conceptions of evolution had not changed and 0.06% did not answer the question (Table 4). Of those that specifically indicated the nature of these changes, five attributed the change to a more complete and "tighter" view of evolution as a result of the class content, three noted that earlier fears and attitudes about evolution had been allayed, one noted the new realization of the testability and continued research in the field, and one mentioned a new recognition of the unifying nature of evolution. The following quotes illustrate the explanations given for these changes:

> "As I have learned and gained more information I continue to add to the different parts and I find new parts that apply and provide greater understanding."
>
> "When I was young I viewed [evolution] more as a belief system. I see it now as very straight-forward. it's hard for me to see how anyone could deny it. Changes come about from education - the more I learned, the more obvious it seemed."
>
> "When I was a high school student I thought Darwin was an evil man too [similar to conceptions held by LDS students - a topic discussed in class]. However, as long as I have been teaching, I have been enlightened!"
>
> "Yes and no. Yes, I realized the physical world could dictate - but no - because evolution as a "unifying principle of biology" was clear, but as a teacher trying to help students see their future they needed to really "see" the past!"
>
> "Not complete picture of interrelatedness of all these processes. Galapagos trip made these real as a microcosm of the world."
>
> "Before I studied evolution I didn't appreciate its testability. I thought everything was drawn out and understood. With new molecular techniques, I realize there's a lot of ground we haven't covered."

---------Insert Figure 8 and 9 about here--------

Relationships Between Biology and Evolution

RQ-8: As a result of analyzing the data concerning the relationship between teachers' views of biology and evolution, it became apparent that teachers who included evolution in the pretest/post-test were much more likely to see evolution as an integrating theme in biology or to see the connections between biology and geology with evolution In contrast, teachers who did not include evolution in their diagram of biology were less likely to describe evolution in an integrative manner. The data was collapsed into the four categories shown (Table 5) and this relationship was

found to be significant ($X^2_{(1,0.05)} = 9.27$).

------- Insert Table 5 about here --------

When asked to describe the relationship between the biology and evolution diagrams (Table 6), 27.7% of the teachers made the conceptual leap that evolution could act as the central unifying theme for biology, as expressed in this statement:

> "Just have evolution as the central topic - basically I could add this on to my biology diagram."

However, 22.2% of the teachers simply recognized evolution as a subtopic under the broader umbrella of biology (Figure 10). This idea is illustrated in the following statements:

> "It's a conceptual framework and all things interrelate and support each other to help solve the puzzle. One is a portion of the whole."

> "Evolution is broad, affected by lots of "ologies," but not as broad as biology. Biology is also changing - being shaped by new information."

--------Insert Figure 10 & Table 6 about here---------

Three teachers saw evolution as one of several ways of organizing biology topics. Typically the contrast was made between organizing biology for the evolution question or for biology teaching. This is in contrast to earlier statements during the pretest that indicated that the teachers viewed their schematics of biology and biology teaching to be the same. As explanation for these views, one teacher stated that evolution was "classification instead of ecological" in terms of organization. Another teacher stated:

> "Evolution is at the center of one [evolution diagram] and DNA at the center of the other [biology diagram] - But I don't view them that separately."

Conclusions and Implications for Science Education

In the absence of a control group, it is difficult to make accurate generalizations about the nature of the data presented: the author's primary intention was to document the changes that occurred in inservice biology teachers' conceptions of biology and evolution as a result of a course sequence in Biological Evolution. However, the findings of this study add to the rather small pool of

articles that look at the description of and changes in teachers' knowledge in the areas of evolution and biology.

The teachers in this sample, when asked to describe their conceptualizations of biology, often based these schematics on ecological principles and relationships (RQ-1). Less than 50% of the teachers included evolution in their pre or post course diagrams, despite completing the forms as part of an evolution course (RQ-3). In addition, there was random movement in terms of teachers' inclusion of evolution within their framework for biology, with no increase in the number of teachers that indicated that evolution was a unifying theme in their framework (RQ-5). The omission of evolution cannot be claimed to be the result of teachers describing a schematic of biology as opposed to that for biology teaching since almost all of the teachers claimed the schematics for these two areas to be the same (RQ-2).

The most logical explanation for the inability or resistance of teachers to change their biological conceptions to include evolution may be the presence of previously formed schematics based upon ecology. Many of the teachers in this sample would have completed their formal science education during the 70s and 80s, a time when environmental issues were at the forefront of discussion and the basis of many texts and curricula. It is possible that the conceptions of biology these teachers reported were based upon this implicit framework presented during their own content instruction. Additionally, considering the LDS background of many of the participants and the students who they teach, a framework based upon ecology would be more tenable than one based upon evolution. The shaping of teachers' beliefs about the structure of science content by student preferences and reactions to content has been previously documented (Gess-Newsome, 1991; Gess-Newsome & Lederman, in press). Such pressures and backgrounds may suggest that originally formed frameworks based upon ecology, and reinforced by student reaction, have been very functional for the teachers in this sample. Replacing such conceptions with a new framework based upon evolution simply may have not made pedagogical or conceptual sense.

The content of the course did have significant self-reported effects on the teachers'

conceptions of both biology (RQ-4) and evolution (RQ-6). Though significantly more teachers indicated that their views of biology had changed at the conclusion of the program, the reasons given for these changes on the post-test do not vary significantly from comments made on the pretest. Most teachers credited shifts in biology conceptions to two sources: increased content knowledge and interactions with students; and shifts in evolution conceptions directly to the course content. These findings are consistent with those reported by Gess-Newsome and Lederman (in press). Though the Biological Evolution sequence was not specifically mentioned by any of the students as contributing to the changes in biology, it can be inferred that this is one of the sources of increased content knowledge. In general, with increased knowledge, the teachers felt that their conceptions of biology and evolution became more integrated and explicit, though their overall conceptions of the structure of biology did not shift dramatically.

When asked directly at the conclusion of the course, 50% of the teachers expressed an understanding of evolution as a unifying concept in biology (RQ-6), though this conception was not necessarily reflected in their views of biology. Such results might indicate that teachers only recognized evolution as unifying when asked about it in isolation from other biology topics. The potential implication of this finding is that biology will not be taught using evolution as the unifying theme as a result of this program. More predictably, teachers may continue to teach evolution as one of a large number of compartmentalized units in their classrooms. The integrating nature of this topic may be mentioned in passing as part of the unit, but would not act as an explicit framework for the year's coursework.

Perhaps the most intriguing finding of this study has to do with the relationship between teachers' conceptions of biology and evolution (RQ-8). Those teachers who included evolution in their pre or post-test descriptions of biology were more likely to see evolution as integrative than those teachers who excluded it in their diagrams. This observation may suggest a predisposition of teachers to see biology in either a holistic or fragmented fashion, a finding that should be addressed in future research. Teachers who included evolution in their initial diagrams saw biology in more

global and integrated terms whereas those teachers who could not find a role for evolution in their schematics of biology tended to isolate and compartmentalize evolution content from other biology topics. Though the lack of pretest information from three of the post-test respondents cloud these findings, interesting implications for biology teaching may exist.

If teachers have conceptual structures in place for biology, how can they best be capitalized upon for biology instruction? What implications do these structures have for the science reforms currently being advocated? It seems that conceptions formed early in teachers' careers concerning the nature of biology content structure are tenacious. The teachers in this sample based their structure of biology on ecological principles, potentially due to background experiences as well as personal and student preference and interest. While this structure in and of itself is not harmful and represents a coherent framework upon which to base content understandings, it does little to provide both teachers and students with an understanding of how and why biologists organize biology content understandings and research in the way that they do. Approaching previously held conceptions by providing increased content knowledge of evolution and the unifying role evolution has in the field of biology at the inservice teacher level does not seem to be enough to affect a change in these conceptions. Instead, teacher recognition of the unifying power of evolution may become an additional fact to add into the unit on that subject, but will not overcome the initial conceptions held by teachers.

However, it may be that only a small portion of the population of teachers is predisposed to see biology as integrative as opposed to fragmented. Our hopes in moving science instruction as advocated by current reforms may rest with those teachers. Two possible scenarios may exist. The first would be to find strategies that can shift "fragmented" thinkers into more holistic patterns. Though this may be the preferable strategy, without continued research in this area its feasibility is questionable. The second scenario may be to identify this group of holistic thinking teachers and offer them inservice opportunities. Though this method is more exclusive than inclusive, it may allow us to reap greater rewards in terms of program impacts than dealing with the larger

population of teachers. Concentrating efforts on this group may then allow us to influence a critical mass of teachers in the profession to hold conceptions that more closely resemble those advocated by the national reforms.

Therefore, contrary to the views of many, simply requiring teachers to take greater amounts of coursework in evolution will not be sufficient to change teachers' conceptions to those currently being advocated by the science reform movements. Teaching strategies similar to conceptual change models used for students may be necessary if we wish to supplant teachers' previously formed biology structures with those advocated by the reforms. Or, we may need to reassess the value of conceptually integrated teaching based upon evolution as opposed to ecological frameworks.

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1a. Most people have some sort of a "big picture" of concepts such as **biology**. What terms/topics/concepts/principles make up your "big picture?" If you were to draw a picture that represents the relationships between these topics, what would that picture look like?

1b. Please describe/explain what you have drawn above.

1c. Have you always thought about biology in this way? Yes/No. If no, how and why have your thoughts changed?

2a. Is your "big picture" of **biology teaching** the same as your "big picture" of biology? Yes/No. If not, how are they different? (If it is easier to draw a second picture, please feel free to use the back of this page)

2b. Have you always thought about biology teaching in this way? Yes/No. If no, how and why have your thoughts changed?

Figure 1: PRETEST OF CONCEPTIONS OF BIOLOGY

1a. Most people have some sort of a "big picture" of concepts such as **biology**. What terms/topics/concepts/principles make up your "big picture?" If you were to draw a picture that represents the relationships between these topics, what would that picture look like?

1b. Please describe/explain what you have drawn above.

1c. Have you always thought about biology in this way? Yes/No. If no, how and why have your thoughts changed?

2a. What is your "big picture" of **evolution**? If you were to draw a picture/diagram that represents the relationships among the ideas/terms/topics/concepts/principles, what would that picture look like?

2b. Please describe/explain what you have drawn above.

2c. Have you always thought about evolution in this way? Yes/No. If no, how and why have your thoughts changed?

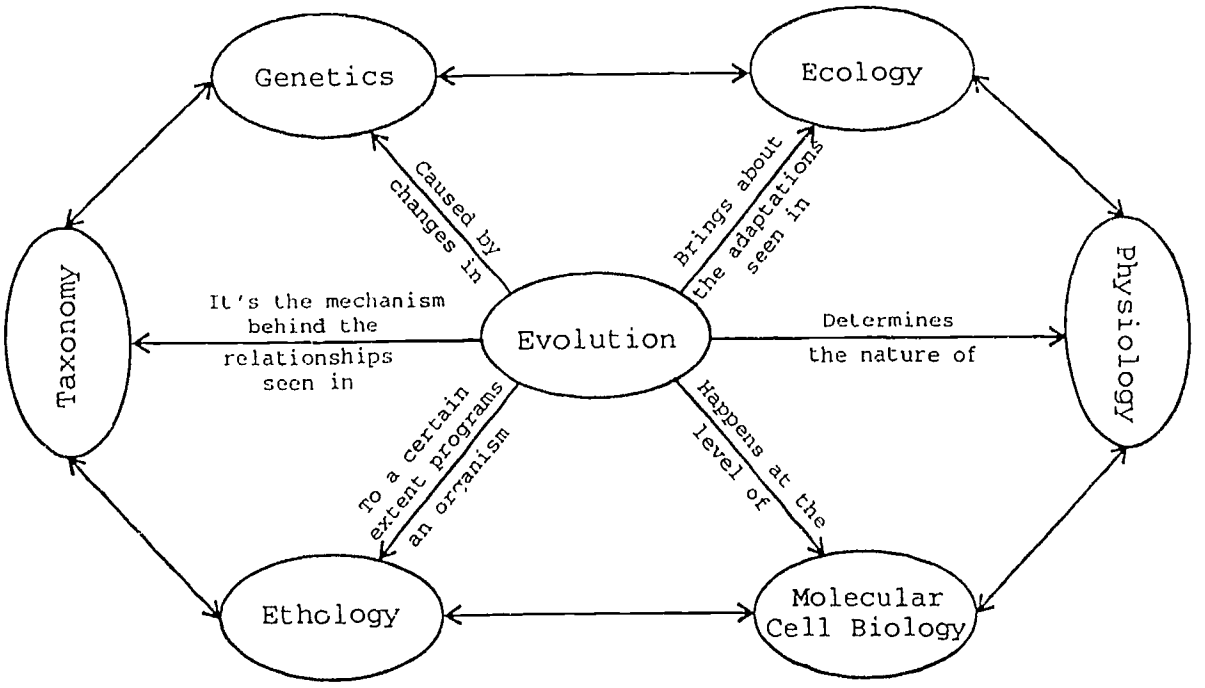
2d. How is the diagram of **evolution** similar/different than the one you drew for **biology**?

Figure 2: POSTTEST OF CONCEPTIONS OF BIOLOGY

Table 1: Pretest Conceptions of the Role of Evolution in Biology and Biology Teaching

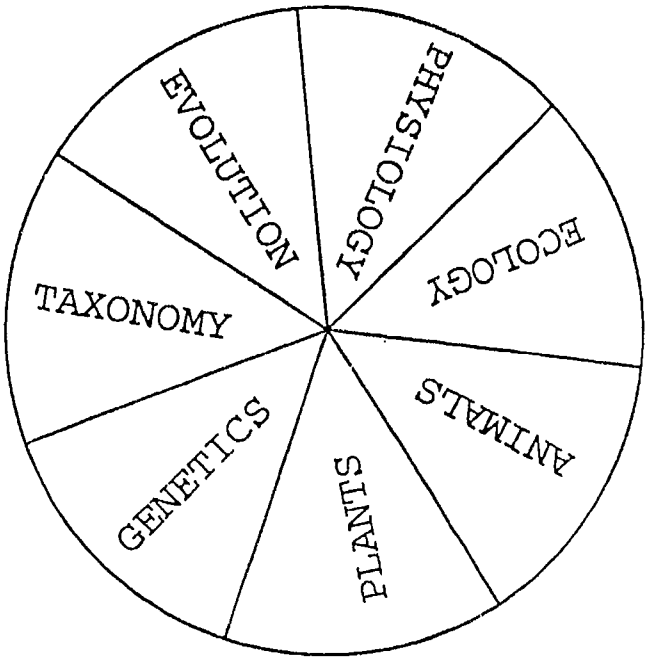
Views of Biology				Views of Biology Teaching	
# of T's	% of T's	Prior View? Yes/No/NA	Role of Evolution in Biology Subject Matter Structure	Biology Teaching Sim/diff/NA	Prior View? Y/No/Na
2	12.5	1/1/0	Evolution the unifying concept in biology	2/0/0	1/1/0
2	12.5	1/1/0	Evolution as a part of biology	2/0/0	2/0/0
3	18.75	2/1/0	Evolution included as last item on diagram/list	3/0/0	2/0/1
6	37.5	4/1/1	Evolution not included	3/2/1	3/2/1
3	18.75	2/0/1	No Answer	2/0/1	2/0/1
16	100%	10/4/2	Total	12/2/2	10/3/3

T's = Teachers, n = 16



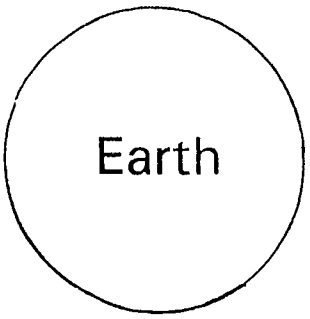
"I could go on. [My diagram] used to be much less integrated than [it is] now. Teaching and acquired knowledge has changed it."

Figure 3: Evolution as a Central Theme in Biology



"All [topics] are part of a whole, i.e., pieces of a pie."

Figure 4: Evolution as a Part of Biology

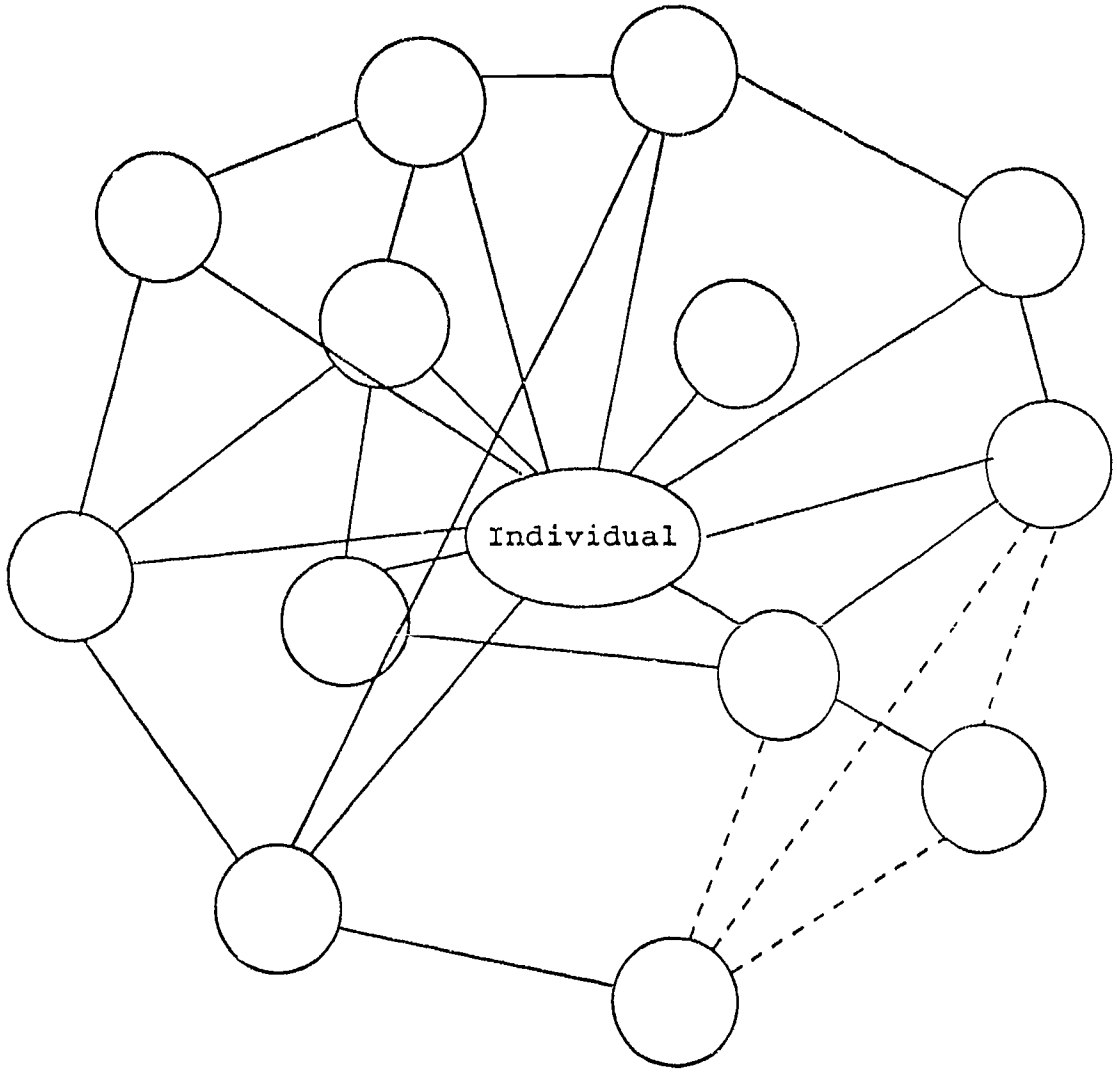


Big Picture of the Earth

Concepts

1. Environment and Pollution
2. Population
3. Distribution of Plants and Animals
4. Cell Concept
   - {Respiration
   - {Parts & Functions
5. Reproduction
6. Genetics
7. Classification
8. Evolution

Figure 5: Evolution Listed Last in Biology Diagram

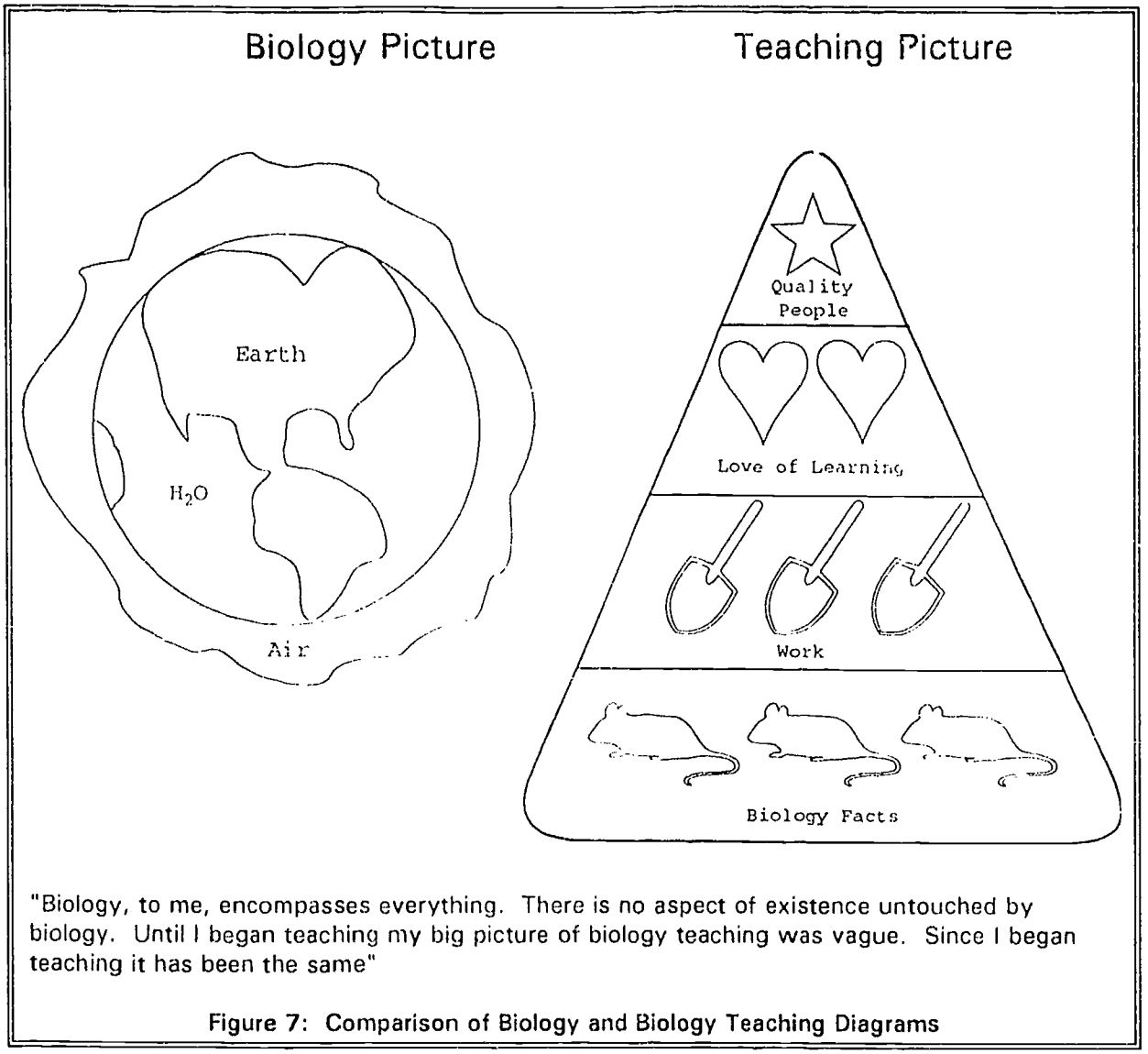


"Biology is a large accumulation of ideas and concepts that affect us, like a large food web, where we are part of the big picture and rather than individual ideas they are all tied together."

Figure 6: Evolution Not Included in Biology Diagram

Table 2: Teachers' Post-test Views of the Role of Evolution in Biology

# of Teachers	% of Teachers	Role of Evolution in Conception of Biology	Prior View? Yes/Maybe/No
2	11.11%	Evolution as the unifying theme	1 / 1 / 0
7	38.88%	Evolution included as one component	3 / 2 / 2
2	11.11%	Unclear if evolution is included	1 / 1 / 0
7	38.88%	Evolution not included	3 / 0 / 4
18	100.00%	Total	8 / 4 / 6



"Biology, to me, encompasses everything. There is no aspect of existence untouched by biology. Until I began teaching my big picture of biology teaching was vague. Since I began teaching it has been the same"

Figure 7: Comparison of Biology and Biology Teaching Diagrams

Table 3: Pre to Post Changes in the Role of Evolution in Teachers' Conceptions of Biology

Pre↓ Post→	Critical	Yes	Last	Maybe	No
Critical	1			1	
Yes		1			1
Last		1			2
Maybe					
No	1	2			2

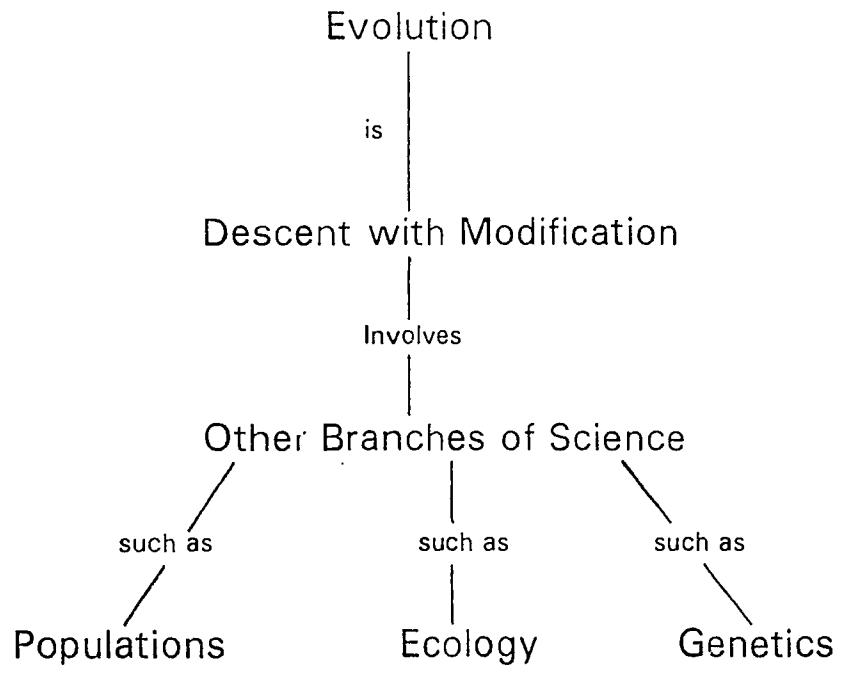
☐ Positive shift = 4, ■ Neutral shift = 4, ▪ Negative Shift = 4, n = 12

Table 4: Teachers' Views of Evolution

# of Teachers n=18	% of Teachers	View of Evolution	Prior View? Yes/No
6	33.33%	Integrative Role in Biology, Geology & Evolution concepts	1 / 5
6	33.33%	Evolution Specific Concepts mentioned	4 / 2
3	16.66%	Combined Evolution and Geology Concepts	2 / 1
1	0.05%	Biology Specific (Phylogeny)	0 / 1
1	0.05%	Historical Development	0 / 1
1	0.05%	No Answer	NA

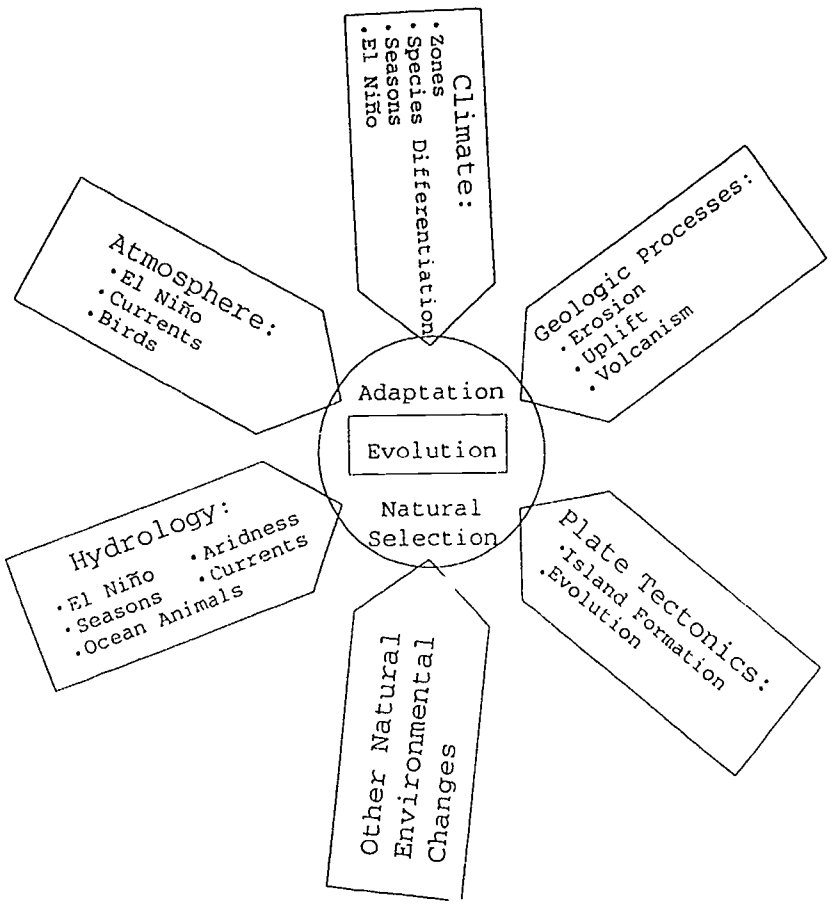
Total = 7 / 10

Evolution is change over time - with variety as produced by sexual reproduction, mutations, crossing over, etc., and environmental conditions acting as the selective agent to determine the "fit" of the population to survive the new or different conditions.



"Again, evolution is a topic or study with many separate parts - integrating and understanding the conceptual relationships equals learning."

Figure 8: Integrated Conceptions of Evolution and Biology

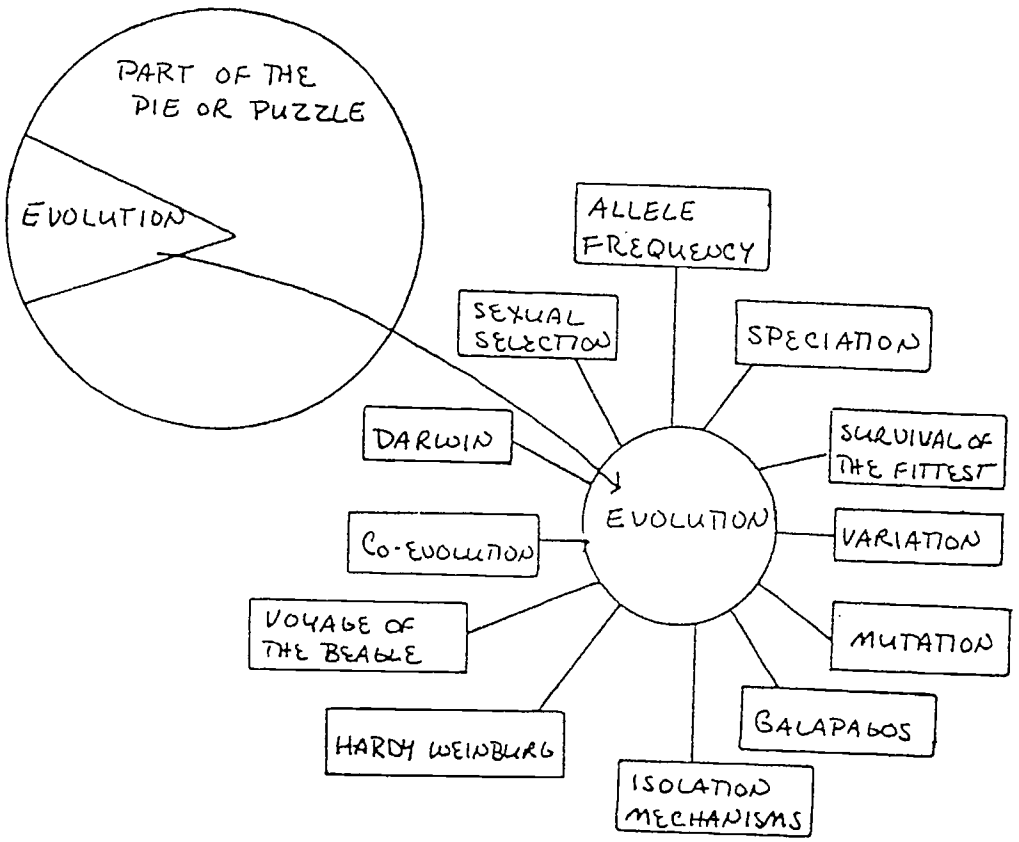


"Many pressures in the environment help select for different characteristics in an organism - these result in adaptation and/or evolutionary changes in species."

Figure 9: Evolution as a Combination of Evolution and Geology Terms and Concepts

Table 5: Comparison of Evolution Diagram to Pre and Post Biology Diagrams

Views of Evolution # of T's n = 18	Critical Pre/Post	Included Pre/Post	Maybe Included Pre/Post	Not Included Pre/Post	No Answer Pre/Post
Integrative - 6	2 / 1	1 / 3	0 / 1	0 / 1	3 / 0
Geology/Evolution- 3	0 / 0	2 / 2	0 / 0	1 / 1	0 / 0
Evolution Specific - 6	0 / 1	1 / 2	0 / 0	3 / 2	2 / 1
Biology Specific - 1	0 / 0	1 / 0	0 / 0	0 / 1	0 / 0
Historical - 1	0 / 0	0 / 0	0 / 0	0 / 1	1 / 0
No Answer - 1	0 / 0	0 / 0	0 / 1	0 / 0	1 / 0



"Evolution is a segment of the earth's knowledge bank and it provides a portion of the puzzle or explanation. Within evolution are many areas and topics which help us understand the earth."

Figure 10: Evolution as Specific Evolutionary Terms

Table 6: Descriptions of the Comparisons Between Evolution and Biology Diagrams

# of Teachers n=18	Description of comparison of evolution and biology diagrams
5	Evolution in the integrative theme
4	Evolution is PART of biology
3	Evolution is the same as biology
2	Evolution and biology differ in linear/integrative arrangement
1	Evolution = classification, biology = ecology
1	Evolution is a process that creates diversity